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RADIOACTIVE MATERIALS AND THEIR EFFECTS ON ENVIRONMENTAL HEALTH

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Oak Ridge National Laboratory
Oak Ridge, Tennessee

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RADIOACTIVE MATERIALS AND THEIR EFFECTS ON ENVIRONMENTAL HEALTH *

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Details of illustrations in this document may be better studied on microfiche.

ERRATA

RADIOACTIVE MATERIALS AND THEIR EFFECTS ON ENVIRONMENTAL HEALTH

Conrad P. Straub, Ph.D.

Page 2, line 6 from bottom. Change to read "half-life or rate ..."

Page 8, photostat, line 5 from bottom. Change to read "inverse square law".

Page 11, photostat, column 4. Radioactive half-life Na^{24} should read 4.4×10^{5} y not 10^{-5} y. Last line on page. Semi colon before MPC.

Page 12, line 10. Correct spelling of "negligible".

Page 17, line 15. Add "of sewage". after gpd.

line 18. Delete "sewer" and add "in the sewer." after flow.

Page 20, line 14. Change above to "alone".

Page 23, last line. Change "99.999965" to "99.999997".

Page 24, line 14. Should read "ground water sources of supply. Approximately 66 per cent of the public water ...".

HEALTH SERVICE
PUBLIC

RADIOACTIVE MATERIALS AND THEIR EFFECTS ON ENVIRONMENTAL HEALTH

In a recent discussion relating to environmental health Mark D. Hollis (1) indicated that public health officials will be responsible for protecting the population against the harmful effects of ionizing radiation. Ionizing radiations result from the disintegration of unstable nuclei, and it is these radiations that are damaging to living tissue. The irradiation in which one is interested may originate from an external source or from radioactive materials within the body. Radiation from an external source may affect the body as a whole, if there is no shielding, or it may be made to affect only certain portions of the body as in the case of x-ray treatment of a tumor. Radiation effects from radioactive materials within the body depend upon several factors: the quantity of radioactive material absorbed in the body; the type of radiation, whether alpha, beta, gamma, etc.; the energy; the point of localization; the rate of excretion from the body; and the half-life of rate of decay of the material. All of these factors are considered in evaluating the maximum permissible concentration (MPC) for each radioisotope in water or air. The MPC values under consideration for release by the Subcommittee on Internal Dose of the National Committee on Radiation Protection are indicated in Table I (2). (Slide).

Table I

TENTATIVE MAXIMUM PERMISSIBLE CONCENTRATION FOR CERTAIN RADIOISOTOPES IN WATER AND AIR

TENTATIVE MAXIMUM PERMISSIBLE CONCENTRATION FOR CERTAIN RADIOISOTOPES IN WATER AND AIR*

Element	μc/cc Water	μc/cc Air
U Nat. (sol.)	x 10^{-4}	1.7×10^{-1}
U Nat. (insol.)	--------	1.7×10^{-1}
U^{233} (sol.)	1.5×10^{-4}	1×10^{-10}
U^{233} (insol.)	---------	1.6×10^{-10}
Pa^{226}	4×10^{-8}	$\times 10^{-12}$
Pa^{222}	$\times 10^{-6}$	10^{-8}
Pu^{239} (sol.)	1.7×10^{-6}	2×10^{-12}
Pu^{239} (insol.)	---------	2×10^{-12}
Po^{210} (sol.)	3×10^{-5}	$\times 10^{-8}$
Po^{210} (insol.)	---------	$\times 10^{-8}$
C^{14} (CC_2)	3×10^{-3}	10^{-6}
H^3	.2	$\times 10^{-6}$
Ca^{45}	$\times 10^{-3}$	$\times 10^{-8}$
I^{32}	2×10	$\times 10^{-7}$
K^{42}	$\times 10^{-2}$	$\times 10^{-9}$
S^{35}	$\times 10^{-3}$	10^{-7}
Na^{24}	6×10^{-3}	$\times 10^{-8}$
Cl^{36}	$\times 10^{-3}$	$\times 10^{-7}$
Fe^{55}	$\times 10^{-3}$	$\times 10^{-7}$
Fe^{59}	$\times 10^{-4}$	$\times 10^{-7}$
Mn^{56}	.2	$\times 10^{-6}$
Co^{60}	6×10^{-2}	$\times 10^{-9}$
P^{32}	3×10^{-5}	$\times 10^{-8}$
Sr^{89}	$\times 10^{-4}$	$\times 10^{-8}$
Sr^{90} , Y^{90}	$\times 10^{-7}$	$\times 10^{-11}$
Ag^{1}	$\times 10^{-3}$	$\times 10^{-7}$
Sc^{133}	$\times 10^{-3}$	$\times 10^{-7}$
Sc^{135}	$\times 10^{-3}$	$\times 10^{-7}$
Co^{60}	2×10^{-2}	$\times 10^{-8}$
Au^{199}	3×10^{-3}	$\times 10^{-7}$
Au^{198}	7×10^{-3}	2×10^{-7}
Cr^{51}	$\times 10^{-2}$	$\times 10^{-6}$
Ni^{59}	7×10^{-3}	$\times 10^{-7}$
Mo^{99}	14	2×10^{-3}

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* Under consideration for release by the Subcommittee on Internal Dose of the National Committee on Radiation Protection in Chicago, Illinois on January 16, 1961. Karl Z. Morgan, Chairman.

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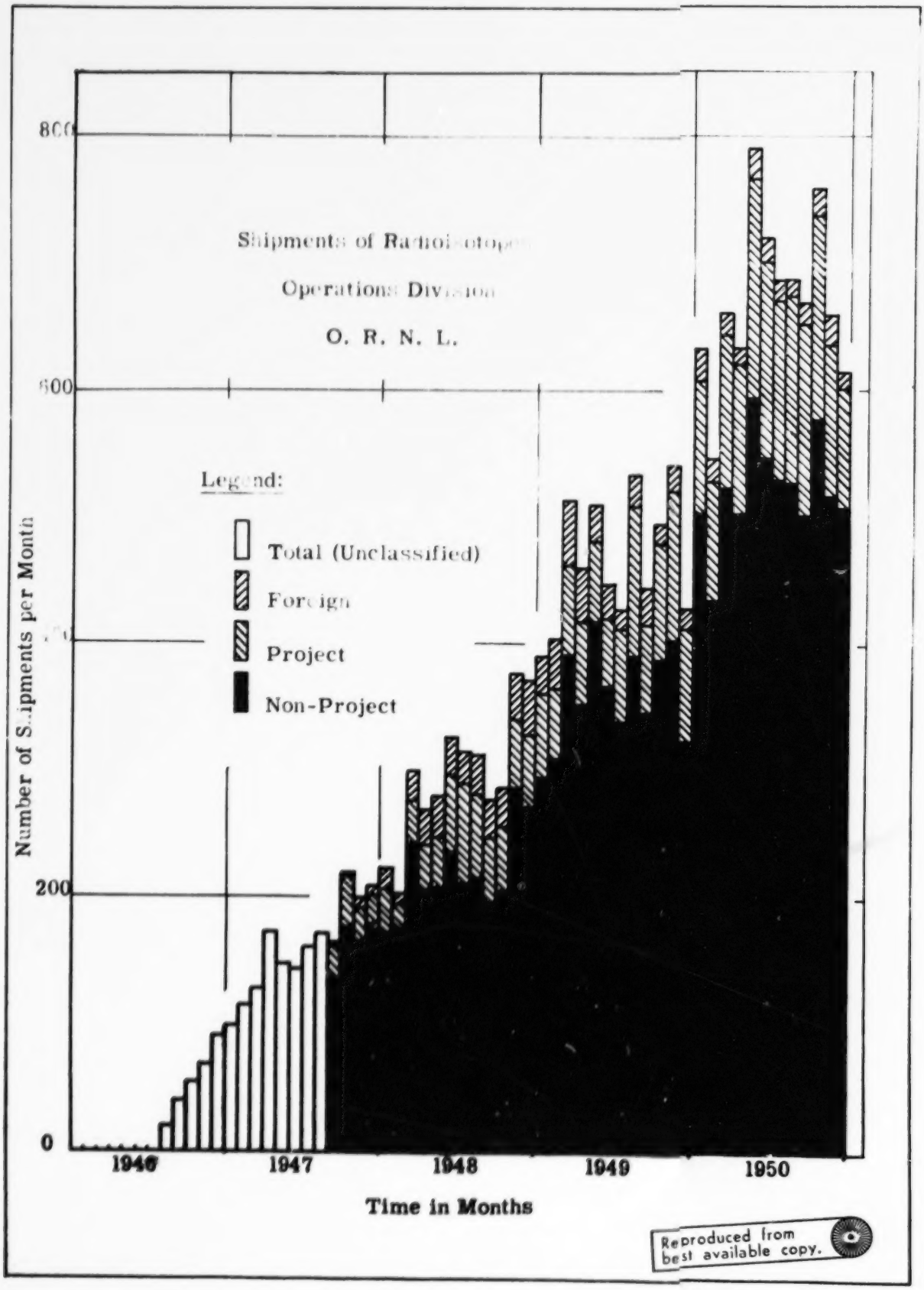
Inasmuch as the Atomic Energy Commission supervises the control and discharge of radioactive wastes from its own operations and users of radioisotopes, the State and local health officials are not directly concerned with the waste products resulting from those operations carried on within the AEC-controlled areas. Public health officials will be occupied with the discharge of wastes into the environment beyond the controlled area of operations; with the discharge into the sewerage system of radioisotopes from hospitals and research institutions; and the industrial use of radioisotopes in manufacturing processes, in industrial radiography, etc. Industrial hygiene engineers will find a broad application in the latter fields.

Radioisotopes are being supplied in increasing numbers as indicated by data available from the Operations Division, Oak Ridge National Laboratory (Figures 1 and 2) (3) (slides). There are six establishments in Georgia that have been or are receiving radioisotopes, namely: Camp Steel Works, Emory University, Georgia Experiment Station, Public Health Service in Savannah, Medical College of Georgia, and the University of Georgia School of Medicine (4). The isotopes shipped to date have included 6 curies of Co^{60} (metal), 23 units of Na^{24} with approximately 15 millicuries per unit, 2 curies of I^{131}, 100 millicuries of P^{32}, and 5 microcuries of Cl^{36} (4). It will be seen that a little over 8 curies have been shipped into Georgia of a total of 1,299.5 curies shipped from the Oak Ridge National Laboratory to non-Commission users during the period August 1946 through December 1950.

Figure 1

NUMBER OF SHIPMENTS OF RADIOISOTOPES
PER MONTH
OPERATIONS DIVISION
OAK RIDGE NATIONAL LABORATORY


Shipments of Radioisotopes
Operations Division
O. R. N. L.
800
600
200
0
Number of Shipments per Month
Legend:
Total (Unclassified)
Foreign
Project
Non-Project
1946
1947
1948
1949
1950
Time in Months
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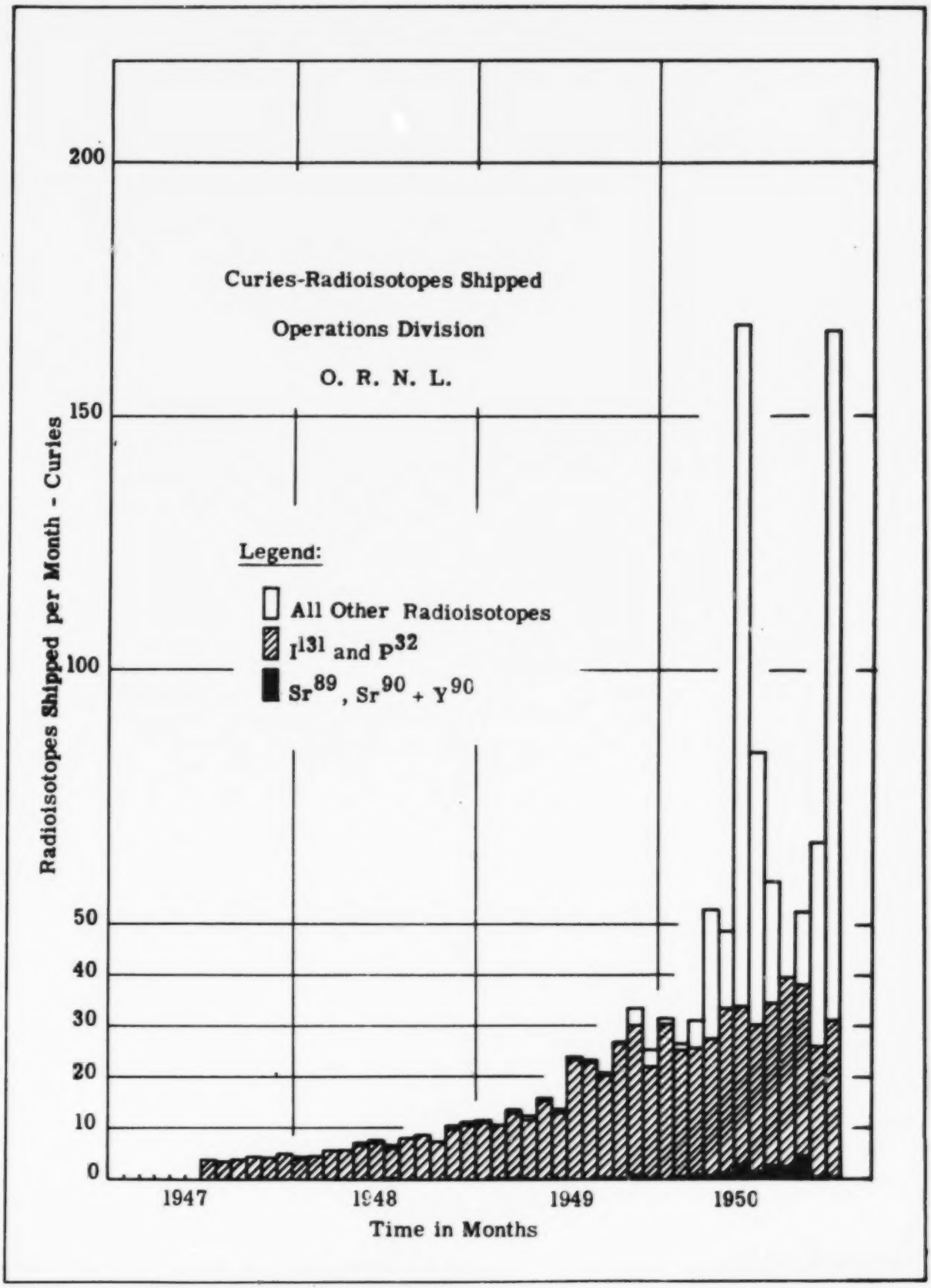
6-a

Figure 2

NUMBER OF CURIES OF RADIOISOTOPES SHIPPED
PER MONTH
OPERATIONS DIVISION
OAK RIDGE NATIONAL LABORATORY


Curies-Radioisotopes Shipped
Operations Division
O. R. N. L.
Legend:
All Other Radioisotopes
I131 and P32
Sr89, Sr90 + Y90
Radioisotopes Shipped per Month - Curies
200
150
100
50
40
30
20
10
0
1947
1948
1949
1950
Time in Months

7-a

HAZARDS

The potential hazards resulting from the use and discharge of these radioisotopes under Georgia conditions will now be considered.

External

Since Co^{60} (metal) is used primarily in radiographic work it will not be discharged as a waste. However, unless suitable precautions are taken to protect personnel from its ionizing radiations, it may be hazardous. The technique used in evaluating the external radiation hazard may be illustrated by means of the following example.

One decay scheme (see slide) that has been given for Co^{60} shows that one beta particle and two gamma quanta are given off in cascade per disintegration. Neglecting beta radiation, a curie of this isotope will emit the equivalent of one curie of quanta of each energy. Substituting in the expression (5)

$$R_f = 6\ C\ E$$

where

R_f = dosage rate in roentgens per hour at one foot.

C = number of curies of radioisotope emitting the gamma radiation (assuming 3.7×10^{10} disintegrations per second to be one curie).

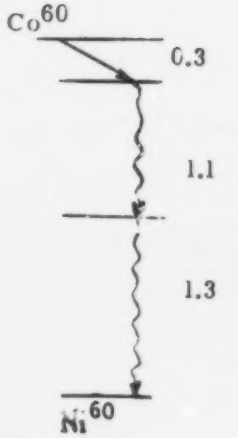
E = gamma energy in Mev per disintegration.

Then

Figure 3

SAMPLE CALCULATIONS - SHIELDING REQUIREMENTS

SAMPLE CALCULATIONS - SHIELDING REQUIREMENTS



From the decay scheme shown, one sees that one beta particle and two gamma quanta are given off in cascade per disintegration. Neglecting beta radiation, a curie of this isotope will emit the equivalent of one curie of quanta of each energy. Substituting in the expression $R_f = 6CE$,* where

R_f = dosage rate in roentgens per hour at one foot = 86.4 r/hr.

C = number of curies of radioisotope emitting the gamma radiation (assuming 3.7×10^{10} disintegrations per second to be one curie)

E = gamma energy in Mev per disintegration.

If we assume that the maximum dose for a 40 hour week will be 0.04 r/week then $\frac{0.04}{40} = 0.001$ r/hr or 1 mr/hr.

The 6 curie source of Co^{60}, therefore, is $\frac{86.4}{0.001}$ or 86,400 times the permissible concentration at a distance of 1 foot. The thickness of lead shield required may be found by the expression $I = I_o e^{-ut}$, which may be transposed to $\log \frac{I_o}{I} = 0.434\ ut$ or $\log \frac{86.4}{0.001} = 0.434 \cdot 0.48t$ where I_o = initial intensity, I = desired intensity, u = linear absorption coefficient, and t = thickness of absorber. Solving, we find t = 23.7 cm or 9.33 inches of lead required for shielding.

To determine the dosage at any distance other than 1 foot the increase square low is applied. For example, if the external radiation at 1 foot is 86.4 r/hr, at 2 feet it will be $\frac{86.4}{(2)^2}$ or 21.6 r/hr. at 3 feet it will be $\frac{86.4}{(3)^2}$ or 9.6 r/hr., etc.

These techniques may be applied when a point source of gamma activity is under consideration.

*Then $R_f = 6 \times 6 \times (1.1 + 1.3) = 86.4$ r/hr at one foot.

9-a

$R_f = 6 \cdot 6 \cdot (1.1 + 1.3) = 86.4$ roentgens/hour at one foot.

If we assume that the maximum dose for a 40 hour week will be 0.04 r/week,

then

$$\frac{0.04}{40} = 0.001 \text{ r/hr or 1 mr/hr.}$$

The 6 curie source of Co^{60}, therefore, is

$$\frac{86.4 \text{ r/hr}}{0.001 \text{ r/hr}} = 86{,}400$$

times the permissible concentration at the 1-foot distance. The thickness of lead shield required may be found by means of the expression

$$I = I_o \, e^{-\mu t} \text{ or } \log \frac{I_o}{I} = 0.434 \, \mu t$$

where

I_o = initial intensity

I = final intensity

μ = linear absorption coefficient

t = thickness of absorber in cm.

The thickness of lead required for shielding will be 23.7 cm. or 9.33 inches.

To determine the dosage at any distance other than 1 foot the inverse square law is applied. For example, if the external radiation at 1 foot is 86.4 r/hr, at 2 feet it will be $\frac{86.4}{(2)^2}$ or 21.6 r/hr, at 3 feet it will be $\frac{86.4}{(3)^2}$ or 9.6 r/hr, etc.

These techniques may be applied when a point source of gamma activity is under consideration.

Internal

The remaining substances, I^{131}, P^{32}, Na^{24} and Cl^{36} could conceivably be discharged into the sewerage system after use in research or as therapeutic agents. These substances have MPC values in water or air as indicated in Table II. (Slide).

The amount of radioisotope that we are dealing with on a weight basis is very small. The concentration of material in mg/l represented by the suggested tolerance concentrations for the radioisotopes shipped will be found in Table II. These values indicate that with the exception of Cl^{36} and Co^{60} the amounts dealt with are exceedingly small - quantities of the order of 10^{-10} ppm. Most of you are familiar with concentrations of ppm and ppb but these may be 10 million times lower than the latter. The amount of radioactive material which represents one curie of each of these substances is also indicated in Table II. (Slide).

Table II

CHARACTERISTICS OF RADIOISOTOPES SHIPPED INTO GEORGIA

CHARACTERISTICS OF RADIOISOTOPES SHIPPED INTO GEORGIA

Radioisotope (1)	Suggested MPC Value μc/cc[1] in air (2)	in water (3)	Radioactive[2] Half-Life (4)	λ Decay Content[3] sec^{-1} (5)	mg/curie[4] (6)	MPC[5] mg/liter (7)
I^{131}	3×10^{-9}	3×10^{-5}	8.0 d	1×10^{-6}	0.81×10^{-2}	2.43×10^{-10}
P^{32}	1×10^{-7}	2×10^{-4}	14.3 d	5.59×10^{-7}	3.52×10^{-3}	7.04×10^{-10}
Na^{24}	2×10^{-6}	8×10^{-3}	14.9 h	1.29×10^{-5}	1.14×10^{-4}	9.1×10^{-10}
Cl^{36}	4×10^{-7}	2×10^{-3}	4.4×10^{-5} y	4.99×10^{-14}	4.42×10^{-4}	8.84×10^{-2}
Co^{60}	1×10^{-6}	2×10^{-2}	5.2 y	4.23×10^{-9}	0.87	1.74×10^{-5}

[1] Morgan data

[2] From National Bureau of Standards Circular NBS-499

[3] $sec^{-1} = \frac{0.693}{\text{half-life in seconds}}$

[4] 3.7×10^{10} dis/sec $= \frac{0.693}{T \text{ (half-life in days)}} \times \frac{W \text{ (gram/curie)}}{A \text{ (atomic weight)}} \times 6.02 \times 10^{23}$ (Avagadro's number)

Therefore, W (grams/curie) $= 7.67 \times 10^{-9}\ AT_D$ or W (mg/curie) $= 7.67 \times 10^{-6}\ AT_D$.

[5] $\frac{\mu c}{cc} \times 10^{-6} \frac{\text{curies}}{\mu c} \times 10^{3} \frac{cc}{\text{liter}} \times \frac{mg}{\text{curie}}$ MPC value for water $\times \frac{mg}{\text{curie}}$ value $= 10^{-3} \times 3 \times 10^{-5} \times 0.81 \times 10^{-2} = 2.43 \times 10^{-10}$.

12-22

Some sample calculations follow which indicate the methods that may be used for estimating the degree of hazard resulting from the use and disposal of radioisotopes. The examples will be confined to radioisotopes which have been shipped into Georgia. In the initial calculation the following assumptions are made.

1. The activity is assumed constant - no decay. Actually the radioactive decay of the radioisotope is not negligible as will be shown later for I^{131}.

2. The radioisotope is discharged completely - no loss through usage. Again this effect may not be neglibible and will be illustrated in the case of I^{131}.

3. Each radioisotope acts independently.

4. All radioisotopes, with the exception of the Co^{60} (metal), are received and discharged within one week.

If the number of millicuries of each radioisotope is divided by the tentative MPC value for that radioisotope in water or air, a value in terms of volume is obtained. This volume is equivalent to the dilution required to render the given amount of radioisotope innocuous (innocuous in the sense that no detectable injury, based on our present knowledge, will result from continuous exposure to the radioisotope).

The volumes of water required to dilute the wastes to the tolerance concentrations given in Table II are determined as indicated in Figure 4. (Slide).

These calculations show that approximately 17.84 MG of water would be required to dilute to tolerance all of the radioisotopes except Co^{60} (metal) shipped into Georgia. This volume of water is slightly greater than the volume of water supplied daily to the inhabitants of Savannah (about 14 MGD (6)). With uniform discharge throughout the week approximately 2.55 MGD would be required for dilution or a stream having a discharge of approximately 4 cfs would suffice when radioactive decay is not considered.

The example cited above shows that it is possible to reduce the activity to the MPC value by diluting with water. Another method of dilution proposed is that of isotopic dilution. In isotopic dilution a carrier having chemical characteristics identical to those of the radioactive substance itself is added. The method is based upon the principle that the body (or any living form) does not distinguish between isotopes of the same element. Hence, since it can accept only certain concentrations of a specific non-toxic substance, excesses will be excreted or discharged, and the radioactive form of an element may be diluted with its stable isotope to such a concentration that when taken into the body the amount of the radioactive

Figure 4

DILUTION REQUIRED TO REDUCE AMOUNT

OF RADIOISOTOPE SHIPPED TO TOLERANCE

Radioisotope	Amount Shipped	Dilution Required		
		Cubic Centimeters	Metric Tons	Million Gallons
I^{131}	2 curies	$\frac{2 \times 10^6 \ \mu c}{3 \times 10^{-5} \ \mu c/cc} = 0.67 \times 10^{11}$	0.67×10^5	17.7
p^{32}	100 mc	$\frac{100 \times 10^3}{2 \times 10^{-4}} = 0.50 \times 10^9$	0.50×10^3	0.13
Na^{24}	23 units at 15 mc/unit	$\frac{23\ (15) \times 10^3}{2 \times 10^{-3}} = 0.44 \times 10^8$	0.44×10^2	0.01
Cl^{36}	5 μc	$\frac{5}{2 \times 10^{-3}} = 0.62 \times 10^3$	0.62×10^{-3}	---
			Total	17.84

15-c

form retained will be below the maximum permissible concentration. This is one possible means of reducing concentration by lower forms. Isotopic dilution generally is not required or in some instances not practical.

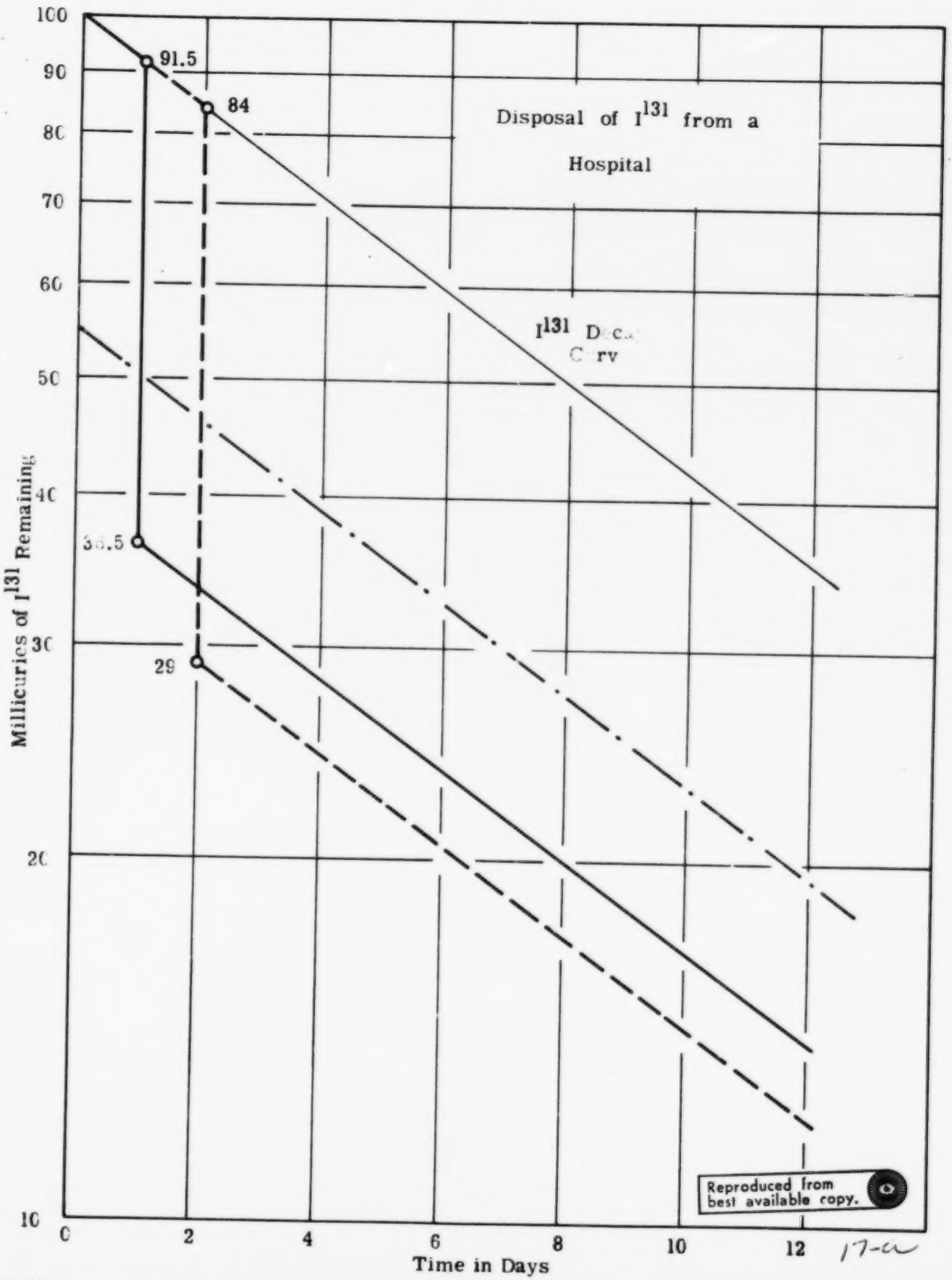
DISCHARGE OF I^{131} FROM HOSPITALS

The effect of decay will now be taken into account. For purposes of illustration let us assume that a hospital in Savannah receives 100 mc of I^{131} for hyperthyroid and cancer therapy, and that a portion of this material will be discharged along with the wastes from the hospital. According to Butrico (7) large quantities of iodine are excreted from the kidneys after administration, and close to 100 per cent of a large dose may be found in the urine over a period of several days. He reports that other investigators found that over a 5-day period normal individuals had urinary excretion of 80 per cent of the administered dose. It may be stated that with most patients approximately 50 to 60 per cent of the administered dose is excreted in the first 24 to 48 hours. These urine wastes constitute the bulk of the radioactive wastes resulting from the use of I^{131}.

If we assume that 100 mc of I^{131} are given to a patient at time zero and that 55 mc of I^{131} are discharged in the urine during the first day, a curve indicated by the heavy solid line in Figure 5

Figure 5

DISPOSAL OF I^{131} FROM A HOSPITAL


Disposal of I^{131} from a Hospital
I^{131} Decay Curve
91.5
84
36.5
29
Millicuries of I^{131} Remaining
Time in Days
100
90
80
70
60
50
40
30
20
10
0
2
4
6
8
10
12
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17-a

is obtained. This shows that during the first day 8.5 per cent of the I^{131} was lost through decay, and that with a discharge of 55 mc in the urine the patient retained 36.5 mc of I^{131}. If we assume that 55 mc of activity are discharged in 48 hours (simplified here to show all discharge - heavy dashed line - on the second day) the patient retains 29 mc of the I^{131} because 16 per cent of the activity is lost through decay. The amount of activity retained by the patient will decrease by decay as shown by the curves. Decay will reduce the 55 mc of iodine discharged as shown by the dot-and-dash line, so that after one day about 50 mc will remain, after two days about 46 mc and after eight days 27.5 mc. The amount of water required to reduce the 55 mc of I^{131} to the tolerance concentration of 3×10^{-5} μc/cc will be approximately 0.5 MG. If the 55 mc of I^{131} are discharged from a 1000-bed hospital there would be available for dilution only about 200,000 to 400,000 gpd. Therefore, the sewage would contain 1.25 to 2.5 times the maximum permissible concentration of I^{131}, if discharged uniformly throughout the day. This activity would be diluted further by the sewer flow. With I^{131}, because of its short half-life, 8 days, there is little likelihood of any radiatic. hazard.

DISPOSAL OF I^{131} BY SEWAGE TREATMENT PROCESSES

Let us follow the sewage containing I^{131} through the sewer to its ultimate point of discharge - directly to a receiving

stream or after passage through a sewage treatment plant. The raw sewage solids will take up some of the radioactive iodine, perhaps up to 20 per cent (8). Bacterial slime on the sewer wall may also account for the removal of additional amounts of radioactivity. If no sewage treatment plant is available, the wastes containing the 55 mc of activity noted above (reduced by an amount for decay) will be discharged into the stream as shown in Figure 6. (Slide) The effect of various sewage treatment processes may be illustrated, in somewhat simplified form, as indicated.

O - A. Travel time in the sewerage system before entering the sewage treatment plant. The loss here is due to decay only.

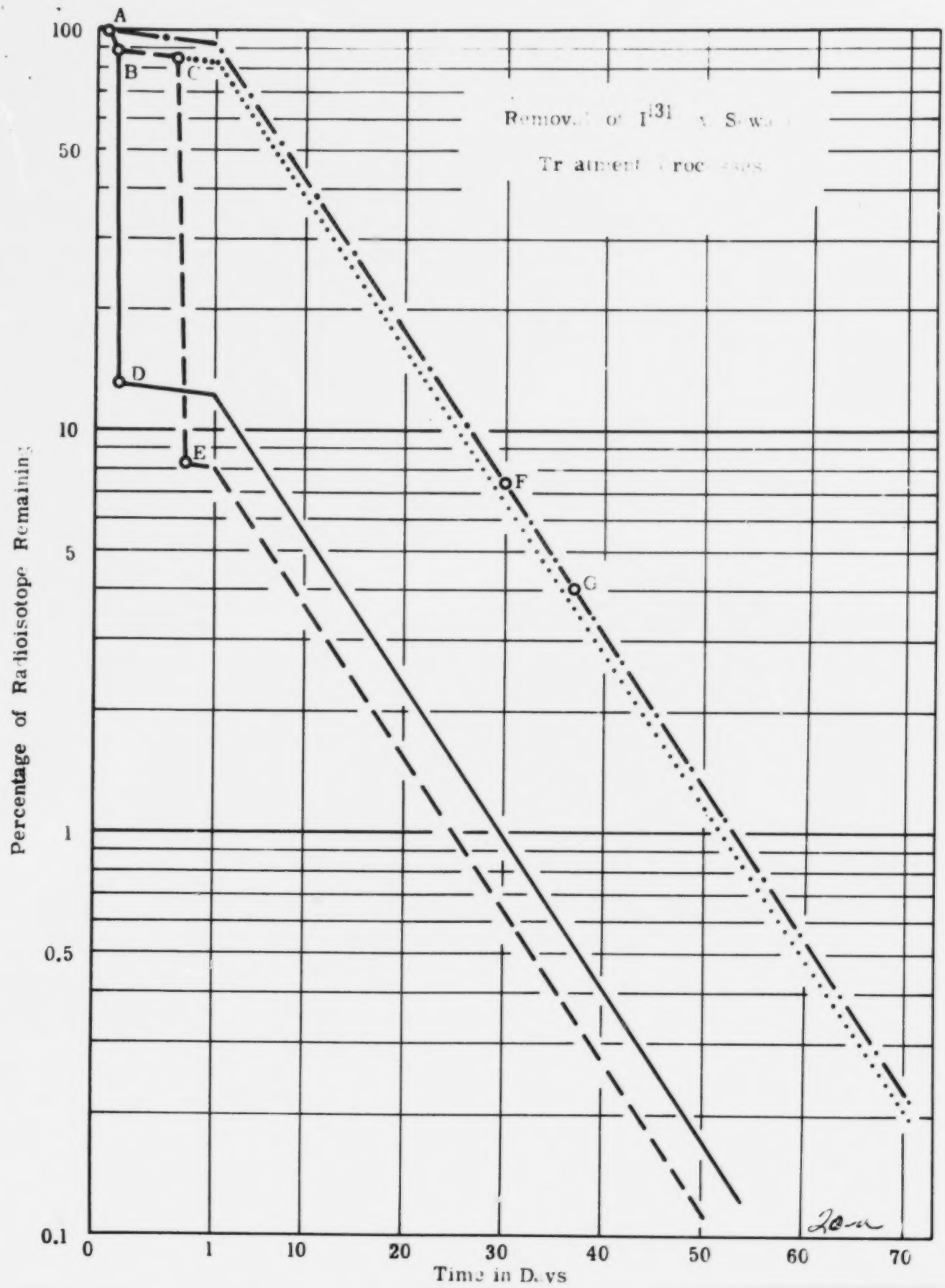
A - B. Removal of radioactive material taken up by suspended solids removed by the primary settling basin, obtained as follows:

20 per cent of the I^{131} is taken up by the suspended solids and 60 per cent of the suspended solids will be removed by sedimentation.

B - D. Removal by trickling filter operating at 2 MGAD rate. Studies by Carter (9) indicated 85 per cent removal by filter and secondary sedimentation.

Figure 6

REMOVAL OF I^{131} BY SEWAGE TREATMENT PROCESSES


A
B
C
D
E
F
G
100
50
10
5
1
0.5
0.1
0
1
10
20
30
40
50
60
70
Percentage of Radioisotope Remaining
Time in Days

D - On. Loss in effluent due to natural decay. In 20 days time activity will have been reduced to about 1.6 per cent.

If the plant is of the activated sludge type with primary sedimentation, aeration and secondary sedimentation, removals as indicated by the dash line in the figure may be obtained.

O - A. Loss due to decay.

A - B. Removal by primary sedimentation.

B - C. Loss due to decay during 12 hour aeration period.

C - E. Loss due to removal of suspended solids in secondary clarifier, assuming 95 per cent removal of initial activity (8).

E - On. Loss by decay.

If primary treatment above is provided the activity will be reduced by sedimentation only as shown by A - B. Beyond B the effect of decay is shown by the dotted line.

The sludge which accumulates from primary and secondary sedimentation may be digested and the activity contained therein will reduce according to the dot-and-dash line. Point F indicates the per cent reduction in activity following 30 days digestion and

point G represents additional decay due to 7 days drying on sand beds. If the sludge is stored, activity will decrease as indicated beyond point G.

Other treatment processes have been suggested for different radioisotopes. The methods that have been investigated include evaporation, co-precipitation, ion exchange, biological processes, metallic displacement, sand filtration, crystallization, etc. Until the use of radioisotopes becomes much more widespread, or reactors are built for power or other purposes the waste disposal problem probably will be a minor one in so far as Georgia is concerned.

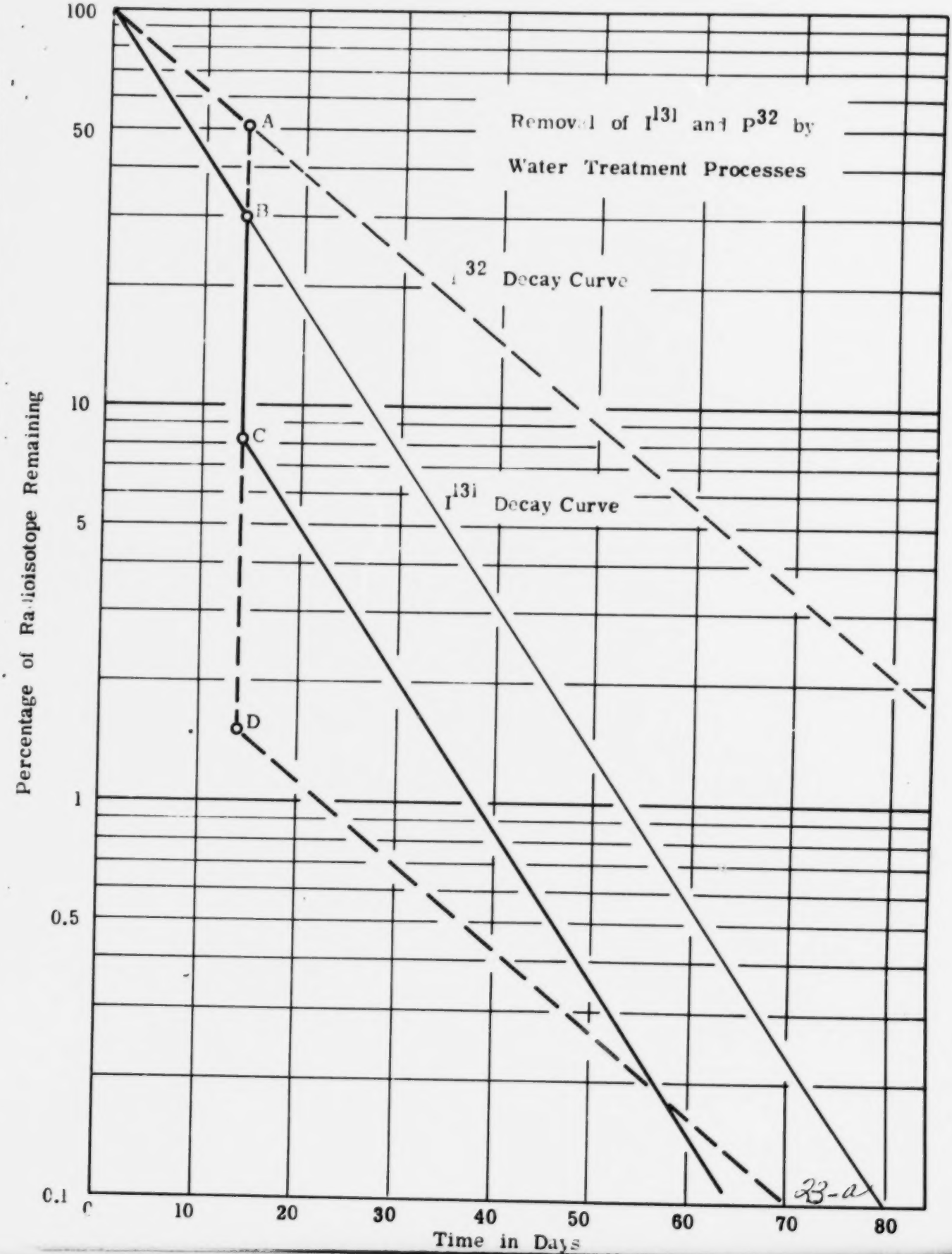
REMOVAL OF I^{131} AND P^{32} BY WATER TREATMENT PROCESSES

Let us now consider what takes place when a stream which contains I^{131} or P^{32} is used as a source of water supply. (See Figure 7). (Slide). In this case we assume that two weeks storage is provided in a reservoir before treatment and the plant includes orthodox coagulation, settling and filtration. Consider first a source containing I^{131}:

Two weeks storage will reduce the activity to that represented by point B. If alum coagulation is used along with sedimentation and filtration no appreciable removal of I^{131} (less than 0.1 per cent) will be obtained. (10). However, the addition

Figure 7

REMOVAL OF I^{131} AND P^{32} BY
WATER TREATMENT PROCESSES


Removal of I^{131} and P^{32} by
Water Treatment Processes
P^{32} Decay Curve
I^{131} Decay Curve
A
B
C
D
Percentage of Radioisotope Remaining
100
50
10
5
1
0.5
0.1
0
10
20
30
40
50
60
70
80
Time in Days
23-a

of small amounts of carbon, copper or silver may increase removals to 75 per cent. This removal is indicated by point C. Chlorination and storage have no effect on removal, although there will be some reduction due to decay as shown by the heavy solid line beyond C.

If the surface source of supply contains P^{32}, which has a half-life of 14.3 days, two weeks storage will reduce the activity to the value indicated for point A. Alum coagulation, settling and filtration will account for a removal of 96-98 per cent (10) which reduces the activity to the value shown at D. Beyond this point decay will account for additional reductions as indicated by the dash line.

Mixtures of radioisotopes may or may not be removed depending upon the radioisotopes comprising the mixture. Mixed fission products activity, for example, will be reduced by approximately 50 per cent by coagulation and settling, and filtration will increase removals to 70 to 73 per cent (8).

At this time I should like to discuss a point which is obvious to many but may be somewhat confusing to some and that has to do with per cent removal. The per cent removal has little significance unless one knows the original concentration of radioactive material. If for example, we have a waste containing an I^{131} concentration of 1 mc/cc, we would have to obtain a removal of 99.999965%

to reduce the original I^{131} present to the tolerance concentration. If our processes will effect a 95 per cent reduction then the highest initial concentration of I^{131} that would be permissible to meet tolerance requirements after treatment would be 6×10^{-4} μc/cc. Any concentration greater than this would result in an effluent containing concentrations in excess of the tolerance values.

Explosion of a nuclear bomb will result in the release of considerable amounts of radioactivity. What the effect on the water supply will be will depend entirely upon the nature of the blast and atmospheric conditions at the time of the blast. Georgia is perhaps a little more fortunate than many states with respect to contamination of surface water supplies following a nuclear explosion, since about 30 per cent of the population served by public water supplies use ground water sources of supply, and approximately 66 per cent of these supplies are from deep wells (6). There is little likelihood that these would become contaminated during an emergency, and they should serve as a source of supply if the distribution systems are not destroyed nor damaged.

CONCLUDING STATEMENT

With the emphasis that is being placed on Civilan Defense activities at present, much has been said about the need for providing facilities for measuring radioactivity. As many of you know this

equipment is rather expensive and may even be in relatively short supply. It is my personal belief that much can be accomplished now through the cooperative use of existing facilities in hospitals and research centers to familiarize public health personnel with the techniques of counting, sample preparation, and measurement of radioactive materials. Such cooperative effort will permit water and sewage treatment plant operators to determine for themselves the amounts of radioactive materials that are being discharged into sewerage systems and water courses and to evaluate the possible potential hazard from this discharge.

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REFERENCES

1. Hollis, Mark D., Environmental Health. A Critique. Public Health Reports, 66: 13, 400-409 (March 30, 1951).

2. Morgan, K.Z., Chairman, Letter of January 23, 1951 to Members of the Subcommittee on Permissible Internal Dose. Minutes of Meeting of the Subcommittee on Internal Dose of the National Committee on Radiation Protection.

3. Straub, Conrad P. Disposal of Radioisotopes - A Method of Evaluating Potential Hazard. To be published in Nucleonics (1951).

4. Personal communication. Operations Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

5. Morgan, G.S. Some Practical Considerations in Radiation Shielding. Isotopes Division Circular B-4 (November 1948). U.S. Atomic Energy Commission, Isotopes Division, Oak Ridge, Tennessee.

6. Public Health Service, Federal Security Agency, Cincinnati, Ohio. Inventory of Water and Sewage Facilities in the United States - 1945 (1948).

7. Butrico, Frank A. Disposal of Radioactive Wastes from Massachusetts General Hospital. NP-1623. Massachusetts Institute of Technology. U.S. Atomic Energy Commission, Technical Information Division, ORE, Oak Ridge, Tennessee.

8. Straub, Conrad P. Treatment and Disposal of Liquid Radioactive Wastes. Prepared as a chapter for the American Chemical Society Monograph on Industrial Wastes (1951).

9. Carter, Melvin W. Master's thesis study on the removal of radioactive iodine (I^{131}) by laboratory sewage trickling filters (1951).

10. Straub, Conrad P. Observations on the Removal of Radioactive Materials from Waste Solutions. Sewage and Industrial Wastes, 23: 2, 188 (February 1951).